Solar Radiometric Data Quality Assessment of SIRS, SKYRAD and GNDRAD Measurements

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Abstract

Solar radiation is the driving force for the earth's weather and climate. Understanding the elements of this dynamic energy balance requires accurate measurements of broadband solar irradiance. Since the mid-1990's the ARM Program has deployed pyrheliometers and pyranometers for the measurement of direct normal irradiance (DNI), global horizontal irradiance (GHI), diffuse horizontal irradiance (DHI), and upwelling shortwave (US) radiation at permanent and mobile field research sites. The quality of these measurements is determined by the radiometer design, installation method, and operation and maintenance practices. Once a measurement is collected, the quality of the resulting data must be assessed with respect to a measurement reference. All broadband shortwave radiometers used by the ARM Program have calibration traceability to the World Radiometric Reference (WRR)[1]. This poster summarizes the basis for assessing the broadband solar radiation data available from the SIRS, SKYRAD, and GNDRAD measurement systems and provides examples of data inspections.

Introduction:

*Solar irradiance measurements from SIRS, SKYRAD, and GNDRAD are made with **pyrheliometers** and **pyranometers** with thermopile-based detectors (Figure 1). These radiometers are calibrated annually at the SGP/Radiometer Calibration Facility using absolute cavity radiometers traceable to the World Radiometric Reference (WRR) (Figure 2). Data quality assessments of the downwelling irradiances are based on the internal consistency of the three independent measurements[2,3] and the expected behaviors of the data normalized to the extraterrestrial values shown in Figure 3 . The reflected solar irradiance is compared with the GHI and surface albedo based on known ground cover conditions (Figure 6).*

Direct Normal (DNI)	***Global Horizontal (GHI)***	***Diffuse (DHI)***	***Upwelling Shortwave***
Measured by a Pyrheliometer on a sun-following tracker	Measured by an unshaded and ventilated Pyranometer	Measured by a shaded Pyranometer under a tracking ball	Measured by a Pyranometer with a horizontal sensor (facing down)

Figure 1. *Types of radiometric measurement instruments.*

Figure 2. *SGP calibration facility, traceable to the World Radiometric Reference (WRR).*

Three Component Equation - *internal consistency test*

GHI = DNI * Cos(Solar Zenith Angle) + DHI

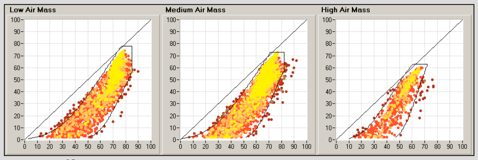


Figure 3. *Example of SERI-QC Gompertz curve, boundaries for the acceptable values for global and direct components. (Kn is the atmospheric transmission of the direct beam radiation from the solar disk, Kt is usually referred to as the clearness or cloudiness index)*

Discussion:

Irradiance measurements from the radiometers forming each SIRS , SKYRAD and GNDRAD station are influenced by the atmospheric condition and ground cover at each location. The work performed by field technicians is critical to the quality of the solar radiation. Here we provide some data quality checks, basic examples related to specific failure modes and corresponding corrective actions or results. Further, the figures below show the output of data quality assessment tools, and failure and corrective actions.

The National Renewable Energy Laboratory (NREL) developed data quality assessment tools such as SERI-QC [3]which are the centerpiece of the ARM data quality analysis processes.

Examples of Data quality Assessment:.

Data Quality:

- *Left most chart shows the most severe flags from among the three components at each time interval. Least error in the dark blue and greatest error in red.*
- *The remaining three charts present the relative solar irradiance for each of the three major components. Kt, Kn, and Kd charts show clearness range where dark blue least clear and red greatest clear.*

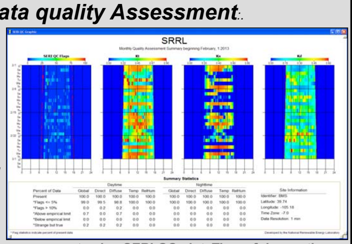


Figure 4. *Data quality assessment using SERI-QC plot. Time of day on the horizontal axis and day of the month on the vertical axis.*

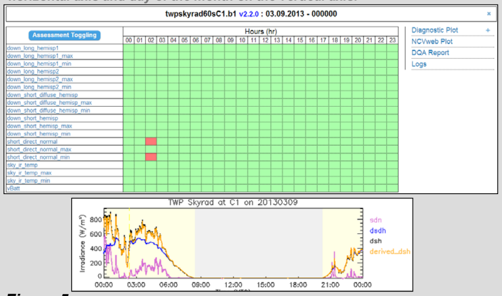


Figure 5. *Data quality showing color coded flags produced on a daily basis with accompanying diagnostic plot.*

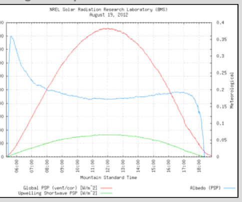
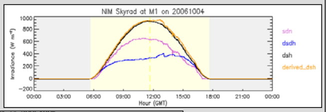


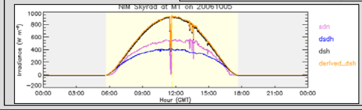
Figure 6. *Comparison of reflected solar irradiance (upwelling shortwave) with GHI and surface albedo.*

Examples of Instrument Failures:

Improper Tracker Operations:

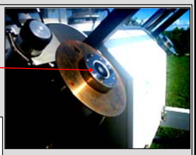
Right -Tilted and time drifted tracker.

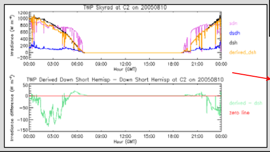




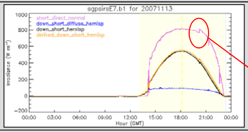
Left-Plot showing tracker conditions after corrective action.

NIP Seal Broken with condensation in window at TWP/C2 (Nauru).





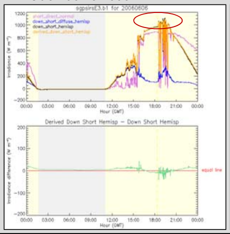
Large discrepancy between derived and measured DSH due to low NIP reading (condensation in NIP window).



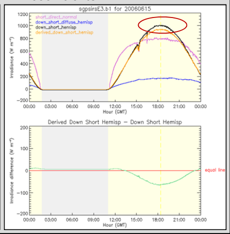
Effect of soiling: Heavy dust (OMIS report) leads to reduction of pyranometer and Pyrheliometer output

Before and after cleaning

Correct program with correct calibration coefficients before site visit on 06/15/2006.



Incorrect program loaded with wrong calibration coefficients.



Uncertainty:

Measurement	Eppley Radiometer Model	Estimated Measurement Uncertainty	Value Added (Correction for Zenith, thermal offset, etc.)
Direct Normal Shortwave (DNI)	NIP	± 3.0%*	± 2.0%
Global Horizontal Irradiance (GHI)	PSP	± 4.0%	± 2.0%
Diffuse Horizontal Irradiance (DHI)	8-48	± 4.0%	± 4.0%
Upwelling Shortwave (US)	PSP	± 3.0%	± 2.0%

-Table modified from Reda et al.[4,5], "Uncertainty Estimates for SIRS, SKYRAD, & GNDRAD Data and Reprocessing the Pyrgeometer Data", ASR Science Team Meeting 2012.
** DNI uncertainty value is estimated with respect to the Système International d'Unités (SI) at greater than 700 W/m²*

Conclusion:

- *ARM has "research-quality" 1-minute broadband solar irradiance data since 1997.*
- *Data quality begins with radiometer performance specifications, installation, and O&M practices (including calibration).*
- *We perform broadband outdoor calibration and/or provide procedures and schedules of calibration to site operations.*
- *We have developed automated data quality assessment tools (such as SERI-QC) now used by the Data Quality Office.*
- *We have identified failure modes and corrective actions.*

Reference:

1. Fröhlich, C., 1991, History of solar radiometry and the World Radiation Reference, Metrologia **28**,111-115. (PMOD/WRC intern: 650) .
2. Stoffel. T., D. Renne, D. Myers, S. Wilcox, M. Sengupta, R. George, and C. Turchi, 2010, CONCENTRATING SOLAR POWER Best Practices Handbook for the Collection and Use of Solar Resource Data, NREL technical Report NREL/TP-550-47465.
3. Maxwell, E.; Wilcox, S.; Rymes, M. , 1993User's Manual for SERI_QC Software- Assessing the Quality of Solar Radiation Data. NREL/TP-463-5608. Golden, CO: National Renewable Energy Laboratory.
4. Reda, I., 2011, Method to Calculate Uncertainties in Measuring Shortwave Solar Irradiance Using Thermopile and Semiconductor Solar Radiometers, NREL technical Report NREL/TP-3B10-52194
5. Reda.,I., T. Stoffel, and A. Habte, 2012,Uncertainty Estimates for SIRS, SKYRAD, and GNDRAD Data and Reprocessing the Pyrgeometer Data, ASR Science Team Meeting, presentation.

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